

## **CHAPTER 6**

### **EDUCATION AND OUTREACH**

The National Space Weather Program (NSWP) and a generally increasing interest in space sciences have created and benefited from educational activities aimed at grade school children, college students, users of space environment data, forecasters, and the general public.

NSF has made one dedicated award for space weather education and outreach activities under the NSWP. This award, to the Space Science Institute, supported the development of educational materials. Though this has been the only outreach product supported by the NSWP, many educational and outreach activities have been supported in connection with on-going programs, and all have demonstrated tremendous success. Examples of these projects are NASA/ISTP outreach, the Windows to the Universe project at the University of Michigan, Creating the Public Connection at Rice University, and the education and outreach efforts conducted by the Space Environment Center in Boulder, Colorado.

Space weather observing and forecasting is growing as an exciting and appealing area of study for a broad spectrum of students. The NSWP will continue to develop efforts that will use this natural interest in space to further national science and mathematics education goals. Those goals, as enunciated in documents such as Benchmarks for Science Literacy (developed by the American Association for the Advancement of Science), National Science Education Standards (developed by the National Academy of Sciences), and the National Council of Teachers of Mathematics Standards, stress the need for students to acquire "process skills." These include the ability to observe and measure, to manipulate those data in meaningful and quantitative ways, to draw conclusions from such investigations, and to communicate those conclusions to others effectively. These documents call for closely tying science to technological and social issues so that students can see the relevance of science in their lives. The NSWP will continue to contribute to achieving these goals by supporting both formal and informal science education.

## 6.1 Formal Education

The Space Science Institute, NOAA Space Environment Center (SEC), NASA, and others are already providing educational materials at the K-12 level through a variety of resource materials and the growing number of Internet web sites related to space weather. For example, the SEC produced the "Solar Physics and Terrestrial Effects" curriculum guide for teachers of grades 7 through 12. It includes text on space weather and its effects, complete with problems and questions, and it includes eight different activities ranging from building a spectroscope, to collecting and analyzing data, to a game exploring the radiation hazards in space. SEC staff members routinely speak at schools, judge science fairs, and participate in teacher training, reaching more than 700 students and teachers in 1997 and 1998 alone. The Space Science Institute partners with educators to create curriculum guides and multi-media materials for use in the classroom.

The interest students have in space means that the materials and programs to support formal science education in schools developed as part of the NSWP will have widespread impact. The program should continue to support the development of instructional modules on problems related to space weather, such as flares, coronal mass ejections (CMEs), the solar wind, geomagnetic storms, and the effect of solar activity on Earth's climate. Although much of the effort to date has focused on grades K-12, modules should be designed to teach science to a general college audience by exposing them to the field's current research. The module on geomagnetic storms, for instance, might be incorporated into an Earth sciences course that explores the near-Earth space environment. Such a module could be designed to demonstrate the importance of the magnetosphere-ionosphere coupling by briefly exploring current magnetospheric modeling efforts and showing how critically the models depend on the way magnetospheric currents enclose the ionosphere.

An example of the manner in which research and education can be integrated is the involvement of students in auroral observations. Using visual scanning and some recording photometers, the students would report on their auroral observations and would analyze the photometer data and send it back to a central site. Similarly, schools could be provided with digital magnetometers for measuring the magnetic field. Students would be instructed on methods to analyze the data for waves and variations and send the data to a central site for archiving. The SEC has begun this project but is seeking additional funding to place magnetometer kits in schools around the country.

## 6.2 Informal Education

In addition to formal science education, informal education plays an important role in the NSWP. The National Science Foundation (NSF) and other Federal agencies stress that to foster a scientifically literate citizenry, science education needs to extend beyond formal education into centers of informal learning such as museums and science centers. These

institutions need to reach people of all ages, interests, and backgrounds. Museum programs and interactive exhibits on space weather themes will be developed in close collaboration with the science museum community, including forging a long-term relationship with the Association of Science-Technology Centers.

The explosion of the World Wide Web in the last five years has carried to the public a wide array of space environment information and more and more articles are appearing in the popular literature. The SEC's Education and Outreach web page includes short papers on selected space weather topics, a primer on the space environment, and a glossary of space weather terms. They also produced a publication entitled "*Web Activities Using Scientific Data*" that includes space weather activities for children. More than 500 people have toured the SEC facilities to gain a better understanding of space weather, its impacts, and how the Nation responds. In addition, the SEC fields several television interviews as well as about 20 print media interactions each year. Sixteen groups have visited SEC between May 1999 and May 2000 to film space weather activities in the operations center.

In a novel approach to public outreach, the SEC cooperated with the U-Haul Corporation to place a space environment graphic design on about 200 of U-Haul's rental trucks. The design highlights the SEC, Boulder, and Colorado in U-Haul's "Venture Across America" series. Other complementary efforts include television programs on The Discovery Channel™ and the development of an IMAX™ film on solar maximum.

In the aviation arena, the Federal Aviation Administration (FAA) distributed a pamphlet entitled "*Why You Should Be Interested in Space Weather*" at the 1999 Experimental Aircraft Association annual convention and fly-in in Oshkosh, Wisconsin. The pamphlet provided a general overview of space weather and its effects with emphasis on impacts on communications and the accuracy and availability of the Global Positioning System (GPS).

### **6.3 Educational Programs for Space Scientists**

Simultaneously, programs will be developed to provide space scientists with the latest information concerning science education and to train interested space scientists to work effectively with students, teachers, and science museums. Efforts by Dr. Bruce Alberts, President of the National Academy of Sciences, and others have shown that the informed participation of scientists can contribute significantly to science education reform. Thus the educational programs and materials developed by the NSWP will be informed by the best current thinking in science education. Within the American Geophysical Union, the Space Physics and Aeronomy section's Education and Public Information Committees have both worked to mobilize the space physics community in support of education efforts tied to the NSWP.

The SEC's 1999 Space Weather Week brought together the operator and research communities for each to gain a better appreciation of the other's activities, giving the

research community an opportunity to better understand the needs of the user and operator community. This exchange is expected to continue in future SEC Space Weather Week events.

#### **6.4 Educational Programs for Operations Personnel and Space Weather Customers**

Education in space weather has historically focused on increasing and spreading knowledge within the scientific community, but less on educating users, operators, and other customers of systems that are affected by space weather. Although considerable progress has been made, better balance in this area is necessary to meet the NSWP goals, which can only be accomplished with advocacy and stated needs from educated users, operators, and policy-makers from the private, non-Department of Defense (DOD) government, and military communities.

DOD has a variety of programs to train space weather analysts, forecasters, officers, and advanced-degree officers. Advanced courses are provided to personnel assigned to duty directly related to space weather observing and forecasting. All newly commissioned Air Force weather officers receive introductory space weather training, and some officers are selected each year to attend graduate space weather programs. Space weather training has also been added to airman and noncommissioned officer weather skill courses that have traditionally focused on tropospheric weather, adding significantly to the number of military personnel with space weather knowledge. In addition to initial skills training, the Air Force Weather Agency has published "*The Space Environment: An Air Force Weather Informational Guide*" to provide study material for Air Force Weather personnel who did not receive formal training in the space environment and its impacts.

Training is also being provided to DOD operators (including those who "drive and track satellites") and to multiple other agencies (customers) conducting operations affected by space weather. Briefings are provided to senior military leadership on the impacts of space weather, and space weather fundamentals and impacts have been added to space operator, space tactics, and other formal military courses. The Air Force Directorate of Weather has also produced an automated, narrated space weather presentation entitled "Space Weather and the Solar Maximum: Impact to Military Operations and What You Can Do About It." Space weather effects have recently been incorporated into several large military exercises and modeling and simulation of the natural environment continues to expand rapidly, including the incorporation of space weather effects in wargaming scenarios.

At the Space Environment Center (SEC) formal training courses are provided for personnel assigned as space weather analysts and forecasters. In addition, the synergy between the co-located operational analysts/forecasters and the scientists of the SEC Research and Development Division affords a unique opportunity. Research staff provide analysts and forecasters with improved understanding of the applicable physics, especially when new or unusual conditions are identified in the space environment, and in

return, operations staff offer insights to the scientists on the practical applications of space weather science.

Civilian customers of space weather information require education, often at short intervals, because of constant turnover of industrial staff. On the other hand, some customers are more knowledgeable about the space weather effects on their own systems because of their life-long involvement. This inhomogeneous mix of customers makes the civilian user education process a multi-tiered problem, one that needs immediate and constant attention. NOAA's Space Environment Center has included space weather tutorials as part of its Space Weather Week and User Conferences in both 1998 and 1999. These sessions were well attended by a range of users and providers and the SEC produced a 90-minute "*Introduction to Space Weather*" videotape based on the 1998 training session. The SEC also publishes its "SEC User Notes" monthly as part of its Customer Focus Group efforts to communicate with their customers.

To enhance the education of current and emerging space weather customers, the SEC has maintained an active relationship with the public media and non-specialized science programs. They launched a campaign to make space weather more understandable and began creating special advisories in plain English to be distributed when major events occurred. Shortly thereafter, SEC developed and announced a major new method of providing space weather information through the use of space weather scales that classify events on a five-level scale that can be applied across three major types of storms. The scales also include the climatology, expected terrestrial effects, and measurement basis for each scale. Though developed for the general public, the scales have been widely accepted as a basis for space weather services by dedicated users and already have extended the use of space weather information to new applications.

The SEC also collaborated with the American Association for the Advancement of Science (AAAS) for a special session during their February 2000 annual meeting entitled "Space Weather and Things that go Bump in the Day." The session featured invited talks on space weather and its effects. A press conference associated with the meeting was one of three major press conferences about space weather organized by NOAA in the last two years.

Along with the recent growth in attention to space weather in the popular literature, many citizen groups, school classes, and science fair aspirants have shown an interest in the field, all of which clearly serve the NSWP. Although the training of analysts/forecasters and the expansion of knowledge through research are fundamental to the program, further outreach to other audiences (to gain advocacy, funding, and requirements) remains a crucial step to success. More information on SEC's public education and outreach efforts is available at their web site at <http://www.sec.noaa.gov/>.